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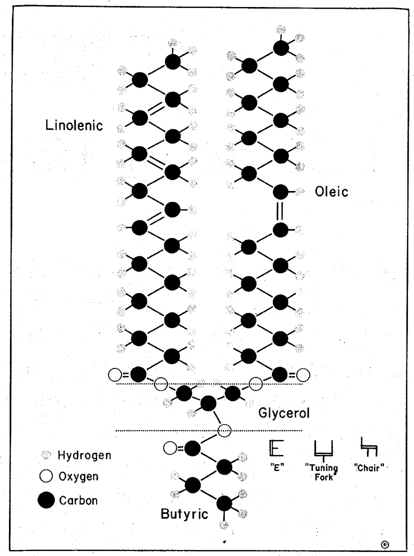
A Matter of Values

WE HAVE come a long way since a man got the idea that the skins of the animals he had been killing for food could protect his body and a later man found he could make the skins more comfortable if he softened them with animal fats or made them more durable by a process like tanning. Our processing has gone far beyond those primitive efforts, but we still have much to learn about such ancient farm products as hides and fats, even though we have the tools of modern research to work with. With them we can probe into the chemistry of plant and animal materials, their molecular and atomic structures, their physical properties, the reactions they enter into, and their response to controllable changes in environment.

Much of our knowledge of the properties of agricultural commodities we have obtained as part of the technological development of new products and processes, but a great part has been obtained in pure research. These are the findings for which no practical use may be evident at the time of their discovery, but from which we may later develop some building blocks necessary to a new product, an improved process, or a more advanced scientific concept. They may be useful in agriculture, medicine, other sciences, and industry. We who do utilization research study the inherent values of wheat, corn, and other grains; such natural fibers as cotton and wool; fruits and vegetables; animal products, such as meat, milk, hides, fats, poultry, and eggs; and oilseeds, sugar, tobacco, pine gum, and many others. The more information we have about their infixed values, the faster progress we can make to meet the increasing demands for better foods, improved feeds, and industrial products.

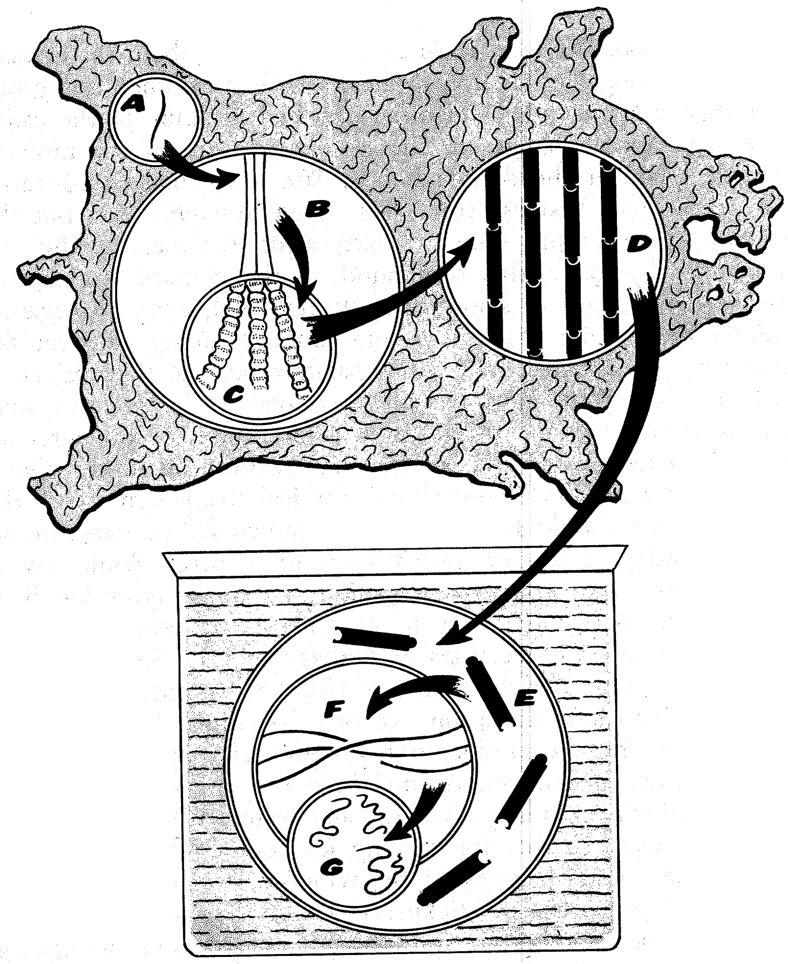
The research on fats is an example of our efforts to discover and utilize the inherent values of farm products. Fats are one of the three classes of organic substances that make up the main body of animal and plant tissues. Fats from animal sources usually are solids at ordinary temperatures. Liquid fats—usually called oils—are mainly of vegetable origin. Fats are considered insoluble in water and have a greasy feel. We can separate them from other materials by melting, pressing, or solvent extraction. Fats consist of carbon, oxygen, and hydrogen, combined in the form of glyceride molecules. A glyceride consists of three usually long-chain carbon compounds, known as fatty acids, attached to a glycerol molecule, which contains three carbon atoms. Fats differ in their fatty acid composition.

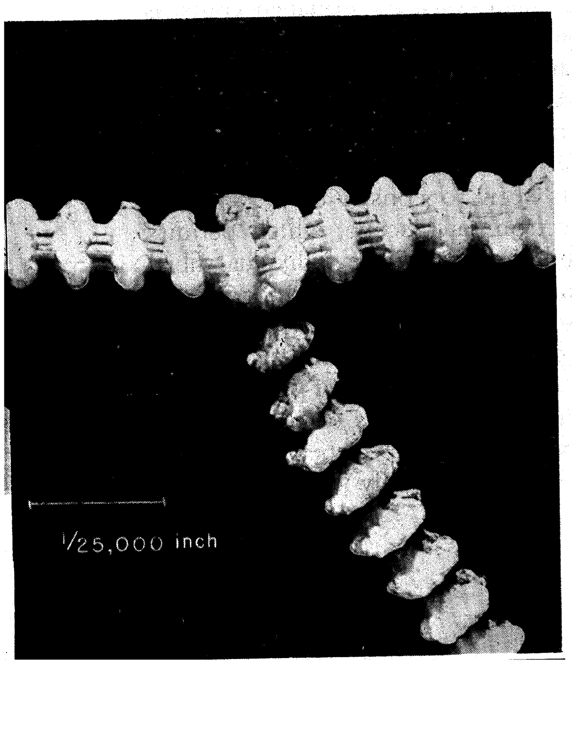


One of the glycerides (fats) found in milk, consisting of two 18-carbon fatty acids, oleic and linolenic, and a 4-carbon fatty acid, butyric, attached to a glycerol. The fatty acids can be attached to the glycerol in many possible configurations, such as a "tuning fork," an "E," or a "chair."

One, for example, might have two long-chain fatty acids, such as the 18-carbon linolenic or oleic acid, and one short-chain fatty acid, which might be as short as the 4-carbon butyric acid in milk fat. Some fatty acids are saturated—that is, they have no double bonds between the carbon atoms. Others, with these double bonds, are unsaturated. Some, like linolenic acid with three double bonds, are more unsaturated than others, like oleic acid, that have only one. The place in the chain where the unsaturation occurs can also vary. These differences in chemical structure—such as chain lengths, number of double bonds, and position of double bonds—explain the differences in the properties of fats. Melting temperature, for example, is generally lower for unsaturated fats and for those with shorter chains. The extent of unsaturation also has much to do with the reaction of fats with the oxygen of the air at ordinary temperatures. Linseed oil is a good base for paints, because linolenic acid, its main constituent, has three points of unsaturation and thus reacts quickly with the oxygen of the air to form a durable film.

We are now searching into even more subtle characteristics of the fat molecule. With our refined techniques for separating and analyzing the components of complex mixtures, we try to establish what the shape of the glyceride molecule is. It might be like a tuning fork, or a chair, or an "E," or something else. The attachment of fatty acids to the end carbons of the glycerol or to the middle carbons makes a difference in the properties of the fat. The stiffness or flexibility of the chain determines the extent of coiling that can take place and hence the reactivity of the fat and its mode



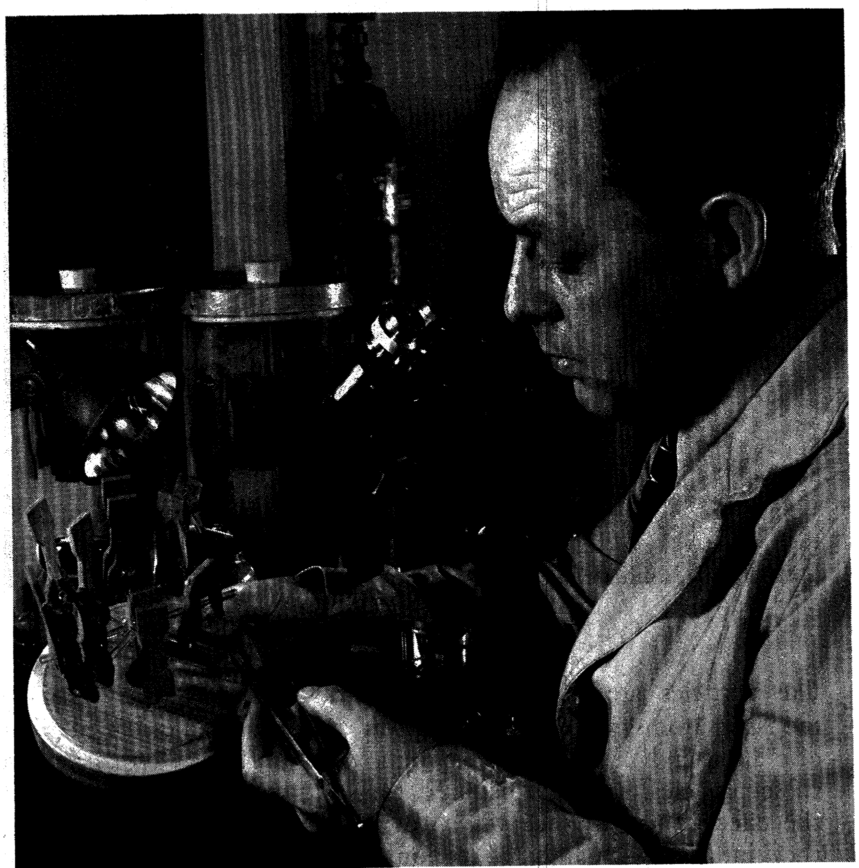


The structure of hide collagen: A schematic representation of (A) visible fiber; (B) fibrils of fiber under light microscope; (C) fibrils under electron microscope; (D) structural arrangement of fibril shown by X-ray diffraction; (E) particles removed from fibrils in solution; (F) coiled formation of the molecular chains of a particle; (G) molecular fragments of a particle. Particles can be re-formed into fibrils with electron micrographic patterns apparently identical to those of native fibrils (C). Entirely different patterns can be formed, as the electron micrograph shows. This fibril, formed from collagen particles by Department scientists, is strikingly different from anything previously reported.

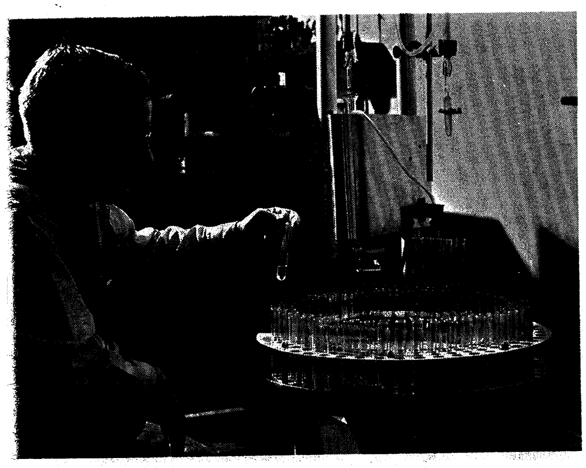
of crystallization. We must learn a great deal more about the branches that occur along the chains, about the effects of chemical groups other than hydrogen that are often attached to some of the carbon atoms, and about changes in the geometric form of the molecule that take place at the double bonds. We must also be concerned with other lipids besides "true" fats. These resemble fats, but they may have, for example, only two fatty acids, the place of the third being taken by some other compound; or the glycerol might be replaced by cholesterol or some other alcohol. Frequently an organism produces these other lipids in minute amounts along with the fats. Often they are difficult to obtain separately because they behave so much like fats. They can give rise to off-flavors in foods or create other problems in the utilization of a fat product. The purer and better characterized fractions of fats we are now obtaining give us a clearer picture of the chemical and physical changes in which they take part. This should lead to a better knowledge of structure and behavior and give us new possibilities for control. Some day we may be constructing our own especially adapted glycerides. Some day, too, we may know how to get rid of the other lipids that cause undesirable side reactions or perhaps prevent their formation.

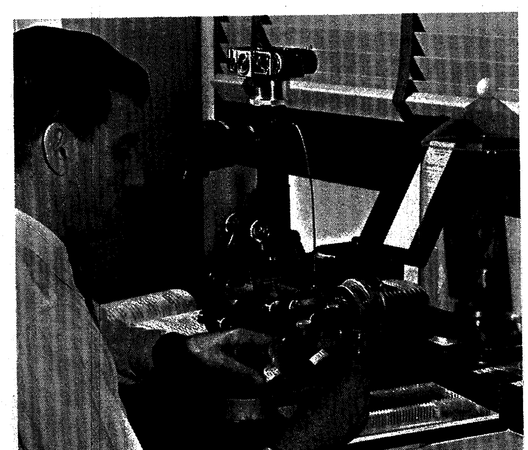
From this glimpse of the nature of fats that we uncover by studying their chemical composition, we turn to animal hide, or skin—an example of how a consideration of physical properties yields information about a product. Animal hide is a complex of proteins, lipids, carbohydrates, inorganic salts, and water. When we consider its ultimate use, whether for making leather or glue products, we are concerned with its physical behavior—with such properties as strength and flexibility or stickiness. To understand why hide behaves as it does, we inquire into the size, shape, and the aggregation of its molecules. The basic component of animal hide is its matrix of complex fibrous protein, called collagen. Collagen contains only a few elements—carbon, hydrogen, nitrogen, oxygen, and a little sulfur—but their atoms are arranged in many combinations to form giant molecules consisting of thousands of atoms.

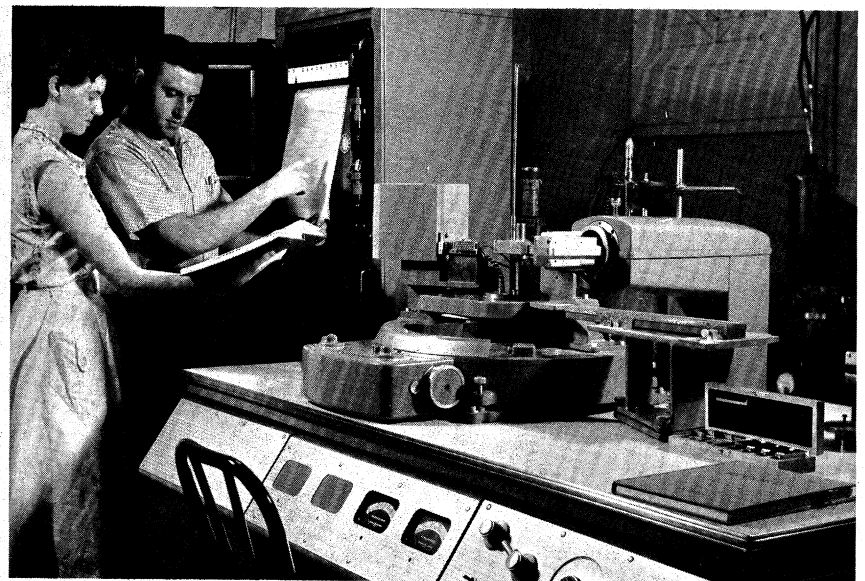
A close look at a piece of animal skin reveals a random interweaving of fibers. Magnified about a thousand times with a light microscope, one of these fibers is seen to consist of a group of smaller fibrils. Studies with an electron microscope, which permits magnification of a hundred-thousandfold, reveals the individual fibril to have a strikingly regular geometric pattern. We cannot see directly the ultimate unit of the fibril, even in the powerful electron microscope. We can, however, explore its organization at the molecular level indirectly by means of its diffraction of X-rays. The patterns we thus obtain tell us that the basic units of the fibril are arranged in a parallel and regular way. When we suspend the fibrils in certain solutions, we find that a few extremely long, thin, rod-



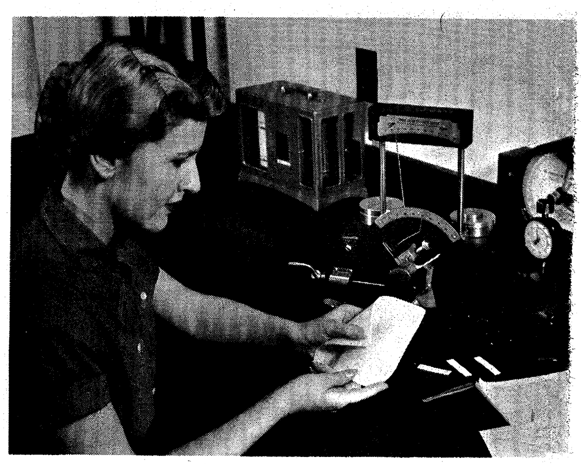
Scientists of the Eastern Utilization Research and Development Division of the Department of Agriculture study the characteristics of farm products.







like particles are removed. Each particle contains more than 50 thousand atoms, which form long, threadlike molecules coiled around one another like strands of a rope. Although we have never seen these particles, we have deduced this information about them from the effects they produce when they are in solution—from the way they interact with light of various wavelengths, from the osmotic pressure they create when isolated on one side of a membrane, from their behavior under an enormous centrifugal force, and from other



effects. We can at present separate only a few of these collagen particles from the fibrils. The rest stay intact. We hope to learn the physical or chemical reason for this when we find out what and where the "hooks" are that nature has provided to keep these particles together in the fibril.

Now if we heat the liquid in which we have obtained these particles, we find that they separate into smaller molecules of unequal sizes and ill-defined shapes. In other words, the strands become unraveled. The solutions of these molecules behave like gelatin or glue. We do not know how and why these particles separate. Perhaps there are weak spots along their chains of atoms. We cannot tell yet because we have no way of determining the strength of a single molecule. Nor do we understand the interplay there is between molecules or even between portions of the same molecule. So we can fragment the collagen particle into smaller units. Can we put it back together? We think the process of subdividing the particles can be reversed. We actually have taken the isolated particles, before they were fragmented, and formed them again into fibrils in the laboratory. Some of our re-formed fibrils under the electron microscope appear to be similar to those of native fibrils, while others we have made produce entirely different micrographic patterns. Does this mean that we can take collagen apart and put it back together again, either in exactly the same way or in an entirely new form? It would appear so, but we are not sure.

So the search for the inherent values of agricultural products goes on. Looking back, we realize that at any given time, the exactness of the information available was dependent on the methods at hand for obtaining that information. We have had to modify our earlier concepts with the development of improved methodology. And we know that later investigators with their more precise instruments will be reexamining what we have done, thus giving the scientific world still better data leading to more uses. This search is an interdisciplinary effort, with chemists and biologists working alongside physicists, spectroscopists, statisticians, electronics experts, and other specialists, to develop more precise methods of measuring and analyzing the inherent values of agricultural products. The fruits of this research are shared by scientists in other apparently unrelated fields. The basic information about lipids and fibrous proteins we look for in the work on fats and hides, for example, is directly applicable in the biological sciences—human physiology, nutrition, animal husbandry, plant biochemistry—as well as such technological fields as plastics, textiles, food processing, and many others. Thus it is its dynamism, as well as its widespread implication in virtually all fields of science, that makes this research on the inherent values of agricultural products rewarding. *(P. A. Wells, G. C. Nutting, L. P. Witnauer, W. P. Ratchford, N. E. Roberts,* and *J. E. Simpson)*